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Sow mortality is associated with meat inspection findings

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Abstract

Sow meat inspection (MI) and mortality data are important sources of information for use in herd health work. This observational study examined whether MI results of sows associate with sow mortality in Finnish sow herds. We also described some MI findings of sows to create basic references in order to encourage their use in herd health work. The project was widely advertised to farmers of sow herds and practicing veterinarians. Ten herds joined the project voluntarily and 36 other herds after they were contacted by the researchers. MI data (carcass weight, lean meat percentage, arthritis, abscesses, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, shoulder ulcers, tail biting, whole carcass condemnations, partial carcass condemnations and kg of meat condemned) were made available by the three largest slaughterhouses in Finland, and sow mortality data were obtained from the National Swine Herd Register for 39 of the study herds for the year 2014. The mean herd size of participating herds was 529 females with a standard deviation of ± 479 and mean annual mortality 9.0% ± 5.2%. As much as 22.8% of the 7437 slaughtered sows had at least one MI finding. Heavy carcasses were less likely to have at least one MI finding. A median (range) of 1.8 % (0-7.2) and 11.8 % (0-34.6) of the sows were recorded to have a whole and partial carcass condemnation, respectively. The most common MI findings were abscesses (5.7 %, 0-16.3), shoulder ulcers (3.6 %, 0-22.9) and arthritis (2.1 %, 0-13.3). In individual carcasses, abscesses were associated with arthritis, shoulder ulcers and pneumonia, which was indicative that these animals most likely had had a systemic infection. Pneumonia findings were associated with pleuritis. At the herd level, the increase of sow mortality by 1% was associated with an increased percentage of slaughtered females with at least one MI finding 0.8% (P=0.01). If sow mortality increased by 1%, the odds ratio for the herd having more than a median percentage of pleuritis was 1.3 (95% confidence interval; 1.01–1.57, P=0.04) compared to the situation of the herd having less than a median percentage of pleuritis. Also, if sow mortality increased by 1%, the percentage of partial carcass condemnations of females increased by 0.4% (P=0.08). These results suggest that high mortality was associated with an increase of some MI findings. MI results of sows should be used in herd health follow-up of sow health.

Keywords

Sow, mortality, meat inspection, condemnations

1. Introduction

About half of the sows in modern pig production are removed from sow herds yearly (Engblom et al., 2007). These animals include culled sows and sows that were euthanized or died on-farm. Culled sows are slaughtered in slaughterhouses, their carcasses are subsequently inspected and, depending on the findings of the carcass inspection, their meat is used for human consumption. The slaughtering procedure is the same as that used for finishing-pigs. The meat inspection (MI) data collected in the slaughterhouse have been effectively used for following-up herd health in addition to inspecting meat for the human food chain.

Originally, MI procedures were developed to reduce food-borne risks to humans (Edwards et al., 1997). Gradually these procedures are also becoming used in extensive epidemiological animal health investigations (Harley et al., 2012b). Consequently, MI recording also includes findings about conditions that are primarily a risk for the animals in addition to those that affect human health (Elbers et al., 1992) and there is thus an increasing need and interest in expanding these MI data to be used as a welfare surveillance tool (Harley et al., 2014). There is, therefore, a clear need to increase knowledge about sow MI findings in general.

Some studies about MI procedures and results have already been published (Harbers et al., 1999, Straw et al., 1986) and their use in herd health improvement work (Straw et al., 1986) and in disease investigations (Cleveland-Nielsen, 2002, Jirawattanapong, 2010). The association between MI findings of finishing pigs and herd parameters has been particulalry studied (Cleveland-Nielsen, 2002, Fraile et al., 2010, Heinonen et al., 2001, Heinonen et al., 2007, Jäger et al., 2012, Maes et al., 2001, Martinez et al., 2009, Merialdi et al., 2012): especially risk factors for MI findings in respiratory organs.

Several earlier studies concentrated on sow mortality, the risks associated with it and possible reasons for mortality (Abiven et al., 1998, Engblom 2008, Jensen et al., 2012, Sanz et al., 2007, Sasaki and Koketsu, 2008). However, there are very few studies published about MI findings in sows (Cleveland-

Nielsen et al., 2004a, Cleveland-Nielsen et al., 2004b, Flesja and Ulvesaeter, 1979). Moreover, textbooks on meat inspection only consider fattening pigs, even though sows also produce a considerable amount of meat. A total of 41 882 sows were sent to slaughter in Finland in 2014 and about 6.8 million kg of sow meat was accepted for human consumption (Eva Kaisti, Finnish Food Safety Authority Evira national records, personal communication 2016), whereas the corresponding meat quantity from fattening pigs was about 176 million kg. Thus, the mean quantity of meat from culled sows is still a noteworthy contribution to the pig meat consumed in Finland.

At some stage of production sows inevitably become diseased or less productive and the farmer decides whether to send the animal to slaughter or to euthanize her on-farm. In addition, some sows die unexpectedly. Some farmers may be more likely than the others not to send a diseased sow to slaughter. Others may try to save disposal costs of sow carcasses and therefore also send some unfit animals to slaughter. Some sows die in the herd or are euthanized on the farm, therefore the meat inspection results may underestimate the extent of the sow health and welfare situation on-farm. We have not found studies investigating the association of mortality in the herd and meat inspection results of sows from the same herds.

The aim of this study was therefore to examine if MI results of sows were associated with sow mortality in Finnish sow herds. We hypothesized that some farms may have fewer MI findings, because they have higher mortality due to euthanasia in-herd. We also describe some MI findings of sows in order to create basic figures to encourage herd veterinarians and herd owners to use them in preventive herd health work in sow herds. We compare our sow data to those of finishing pigs and discuss them. The results concerning the herd-level risk factors for culling, mortality and meat inspection findings in these same herds are presented in another article (Munsterhjelm et al., submitted).

2. Materials and methods

This observational study between mortality and MI is a part of a larger sow longevity project collecting information from Finnish sow herds. The websites of the three largest slaughterhouses in the country recommend the longevity project to their client herd producers. The longevity project was also advertised on the websites of the research group, Finnish Pig Producers and Animal Health ETT and in Facebook of the advisory organization ProAgria. The research personnel also spread the information about the longevity project in farmers' meetings and in farmers' professional journals. Finally, all client farms of the three largest slaughterhouses received an invitation letter to participate in the project. A total of 46 herds participated in the sow longevity study. Ten of them informed the research group voluntarily about their willingness to join the project and allowed the researcher to visit the herd for data collection. The rest of the herds in this study consisted of a convenience sample of herds after making telephone contact between the research personnel and the producers. Mortality and slaughterhouse data were collected from these 46 herds for the year 2014.

Sow mortality data were collected from the National Swine Herd Register maintained by the Finnish Food Safety Authority Evira. Herd owners report their monthly numbers of animals to this register: the numbers of sows and young breeding animals (hereafter females) present in the herd on the first day of each month and the numbers of females found dead or euthanized (hereafter referred to as dead) in the herd each month. Finnish legislation defines a gilt as a sexually mature female pig from mating until the first farrowing, however, we do not know exactly how the farmers in the study applied the term 'gilt'. The slaughterhouses send a report to the National Swine Herd Register the numbers of females they receive from the herds for slaughter each month. These data were obtained directly from the Register for 44 herds that participate in the longevity study for a 12-month period from January to December 2014. The 12-month mean female inventory of the herd was calculated by summing up the number of females on the first day of each month and dividing the sum by 12. The number of dead females were the sum of females reported to have been euthanized or found dead during the whole year 2014. Similarly, the number of slaughtered (culled) animals summed up the females sent to slaughter during the same year. The mortality and culling percentage were calculated as the number of dead females in the herd or slaughtered animals divided by the 12-month mean female inventory. The removal percentage included all females removed from the herds due to death, euthanasia and slaughter.

The MI data of slaughtered females from 40 out of the 46 herds that participated in the longevity study were obtained directly from three large Finnish slaughterhouses. Slaughterhouse information could not be obtained from those study herds that sent their animals to small slaughterhouses that were not able or willing to transfer these data for the research purposes. The data obtained included individual, animal level MI findings for each slaughtered animal: carcass weight, lean meat percentage of the carcass and meat inspection findings (arthritis, abscesses, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, shoulder ulcers, tail biting, whole carcass condemnation, partial carcass condemnation, and kg of condemned meat). Detailed sow culling reasons from farm records were not available for the study. Therefore, comparisons between MI findings and the most important culling reasons, namely reproductive failures and locomotion problems, could not be carried out. In order to numerically compare the levels of MI findings in sows and finishing pigs, we also obtained data for finishers (n=1 998 124) from Evira Finland's Food Safety Authority's national records by collecting information from pigs slaughtered in all slaughterhouses in Finland during the same time period as for the sows investigated in this study.

When calculating the financial loss caused by carcass condemnations, the producer price of 0.8474 €/kg for sow meat was used.

The complete set of data (both Swine Herd Register data and MI findings) for this observational study investigating the association between mortality and MI findings was obtained for 39 herds.

2.1 Statistical analyses

Herd level data

The unit of interest was a herd. All outcome variables were originally expressed as herd level percentages. First, descriptive statistics were calculated for all outcome variables (abscesses, arthritis, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, tail biting, shoulder ulcers and a summary variable “condemnation due to any reason” in addition to lean meat percentage, partial or whole carcass condemnations and kg of condemnations). Because of clear differences in coding practices regarding pleuritis between different slaughterhouses (Hälli et al., 2012), descriptive statistics for pleuritis were calculated separately for each slaughterhouse. Descriptive statistics were also calculated for "low mortality herds" and "high mortality herds", separately, according to their mean annual mortality percentage.

Outcome variables were modelled as continuous variables unless categorizing of the variable was required by the data distributions. The median was used as a cut-off point in categorizing. The variables "carcass with at least one meat inspection finding", abscesses and partial carcass condemnations were modelled as continuous variables and thus, linear regression was used for analysis. For the variable "whole carcass condemnations", the outcome variable was log transformed to correct any obvious heteroscedasticity. The variables of arthritis, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, shoulder ulcers and kg of meat condemned were modelled as binary variables and thus, logistic regression was used for analysis.

The main explanatory variable used was “mortality”, which was modelled as a continuous variable unless categorizing of the variable was needed. In the latter case, the mean was used as the cut-off point. For “at least one meat inspection finding”, abscesses, arthritis, pleuritis, pneumonia, liver condemnations, shoulder ulcers, partial and whole carcass condemnations and kg of condemned meat, “mortality” was modelled as the continuous variable. For milk spots the “mortality” was modelled as a binary variable.

Other explanatory variables were “herd size" (only adult female pigs), "carcass weight”, “lean meat percentage”, “slaughterhouse" and “gilts” (=proportion of gilts out of female pigs). Crude associations (only one explanatory variable in the model at a time) between outcome and explanatory variables were evaluated using liberal p-value of 0.2 as a “drop-out/keep-in” criterion.

Finally, multivariable models (either linear or logistic regression, depending on the outcome variable) were built for the outcomes (meat inspection findings) abscesses, arthritis, liver condemnations, milk spots, organ condemnations, pleuritis, pneumonia, shoulder ulcers, whole or partial carcass condemnations and kg of condemned meat. The corresponding random effects models including herd as a random factor were built, but no difference was observed compared to models without the random effect. Thus, random effects models were not used.

During model building for herd level data, assumptions of linear regression model were evaluated by performing a formal test for heteroscedasticity (Breusch-Pagan and Cook-Weisberg test) and a normal distribution of errors test (Shapiro-Wilk W test), a graphical evaluation of residuals and linear prediction and of residuals plotted against outcome. If any concerns were detected, suitable modifications in explanatory variables were performed as described earlier in the text. After fitting the final linear model, variance inflation factors were calculated and evaluated.

Diagnostics for logistic regression included evaluation of Pearson goodness of fit test and the ability of the model to correctly classify the outcome.

Individual level data

Individual level data were used in testing two outcome variables, “abscesses” and “pneumonia”. The unit of interest for these analyses was an individual female pig. First, descriptive statistics were calculated for all variables. We used categorical variables “slaughterhouse”, “arthritis”, “shoulder ulcers”, “pleuritis” and “pneumonia” as explanatory variables for the outcome variable “abscesses” (yes/no). Correlations between explanatory variables were evaluated using the “correlate” function in STATA. Despite multiple comparisons no Bonferroni corrections were used, because of the preliminary type of analysis. Moreover, no strong correlations were detected. Unconditional associations between the outcome and explanatory variables were evaluated using the liberal p-value of 0.2 as a drop-out/keep-in criterion. Finally, a multivariable random effects model was built for the outcome with explanatory variables “arthritis”, “shoulder ulcers”, “pleuritis” and “pneumonia” with the herd as a group-level variable.

The second outcome variable tested was the categorical variable “pneumonia” (yes/no) and the explanatory variables used were categorical variables “pleuritis” and “slaughterhouse”. A logistic model was built that contained both the abovementioned variables. The corresponding random effects model, which included herd as a random factor was built, but no difference was observed compared to the model without the random effect. Thus, the random effects model was not used. Similar model diagnostics as for herd level data were performed.

All statistical data analyses were performed using Stata 14.0 (StataCorp LP, Texas, USA).

3. Results

3.1. Descriptive statistics and crude analyses

The data consisted of records from 39 Finnish sow herds that had sent their animals to one of the three largest slaughterhouses in Finland (9 herds to slaughterhouse A, 17 herds to slaughterhouse B and 13 herds to slaughterhouse C). These herds had a mean of 529 females (standard deviation, sd/±/479), and totalled 20 614 females in the study (2 206 gilts and 18 409 sows). During the follow-up time of the year 2014, the study herds sent altogether 7 531 females to slaughter, resulting in a median culling percentage of 32.8 % (range 21.5-80.3) of females in a herd. The herd mortality (females found dead or euthanized) was a mean of 9.0% (±5.2%) and a median of 7.8% (range 0–18.2 %). A total of 9 742 (44.1%) animals were removed from the herds, i.e. they were found dead, euthanized or sent for slaughter.

We were able to obtain MI findings for 7 437 females, which was 98.8% of all females sent to slaughter during the study period. Their mean carcass weight was 188.8 kg ± 12.9 kg and the median lean meat percentage was 60.0% (range 48.8–63.4 %). The slaughterhouse records of the sows in the study herds are presented in Table 1 together with the MI results of all the finishers slaughtered in Finland during the same time period.

A total of 38 038 kg of carcass condemnations were recorded during the study, which was a mean of 975 kg ± 1350 kg per herd (median 513 kg and range 0–5366 kg). When calculated for each herd, a mean of 4.4 kg ± 3.9 kg per slaughtered female was condemned (median 3.2 kg and range 0–16.1 kg), corresponding to a mean of 826.5 € per herd and 3.7 € per slaughtered female.

Descriptive results and crude analysis of the MI findings divided by the classification of the herds according to their mortality (higher or lower than the mean of the study herds) are presented in Table 2.

3.2 The association between mortality and MI findings

Multivariable modelling revealed that mortality of the females was associated with some of the MI findings of the slaughtered animals in the study herds. When mortality increased by 1%, the percentage of slaughtered females with at least one MI finding increased by 0.8% (P=0.01). Similarly, when carcass weight increased by 1 kg, the percentage of slaughtered females with at least one MI finding increased by 0.3% (P=0.04). When mortality increased by 1%, the odds ratio for the herd having more than median percentage of pleuritis was 1.3 (95% CI, 1.01–1.57, P=0.04). Mortality also tended to have an association with partial carcass condemnations. When mortality increased by 1%, the percentage of partial carcass condemnations of females increased by 0.4% (P=0.08).

Mortality was not associated with whole carcass condemnations, kg of carcass condemnations or with MI findings due to abscesses, arthritis, liver condemnations, milk spots, organ condemnations, pneumonia, or shoulder ulcers.

3.3. Associations of MI findings in individual animals

On the individual animal level, the MI finding “abscess” was associated with some of the other MI findings, namely: arthritis, shoulder ulcer and pneumonia (Table 3). The intra class correlation (ICC) of the final model was 0.042, which indicated that most of the variance was within the herds. Similarly, sows that had pneumonia recordings in MI were more likely to have pleuritis (Table 4).

4. Discussion

Sow mortality of herds involved in the study was associated with MI findings. All MI recordings were more common in high mortality herds compared with those in low mortality herds, but the difference was statistically significant after modelling for only two MI findings, namely: pleuritis and carcasses with at least one MI finding. Partial carcass condemnations showed a tendency (P=0.08) to be significant.

The 9% annual mortality corresponds well with the mortality rates reported by other studies (Abiven et al., 1998, Engblom, 2008, Jensen et al., 2012, Sanz et al., 2007, Sasaki and Koketsu, 2008) and the figures from the National Herd Health Register, Sikava (Nikunen and Kortesniemi, 2014). However, only a median of 32.8 % of the animals had been culled annually from the herds being clearly less than that reported elsewhere. The figures differ considerably between different countries. For example, a culling percentage of 51% and mortality of 9% was reported in the U.S.A. (Mote et al., 2009). In Hungary, the corresponding figures were 45% and 16% (Balogh et al., 2015). In addition, we were able to obtain data only from volunteer herds, not from randomly selected herds, and this may have led to selection of better managed herds. Our study herds were also noticeably larger than the mean sow herd size for Finland, which was 128 sows per herd for 2014. Therefore, these results cannot be generalized to the whole sow population in Finland.

In contrast to our hypothesis, high mortality was not associated with a low percentage of MI findings. In the crude analyses, high mortality herds had a higher percentage of most MI recordings. According to multivariable model analyses, there was an association between mortality and the MI recordings “at least for one MI finding”, “pleuritis” and a tendency towards an association for “partial carcass condemnation”. These results suggest that there may be some health or management problems in our study herds. Similar studies that were conducted on finishing pigs have shown that pleuritis was associated with different infectious and non-infectious herd factors (Jäger et al., 2012, Martinez et al., 2009, Merialdi et al., 2012).

A lost sum of 3.7 € per slaughtered female due to condemnations should not be overlooked. Financial implications have not usually been published in conjunction to these kind of data, even though they are of great commercial importance. Harley et al. (2014) studied the prevalence of welfare-related lesions on carcasses of finishing pigs and calculated that the financial loss associated with carcass condemnations and trimmings for the producers was 1.10 € per study pig. This emphasizes the fact that carcass condemnations are not only related to sow welfare, but also affects the producer farm’s economics.

The MI data showed that findings in sows seem to differ from the results obtained from finishing pigs. When observing only the crude figures (Table 1) without statistical testing, we can see that in our data obtained for finishing pigs that pneumonia, pleuritis, milk spots, arthritis and tail biting are more common than in sows, whereas in sows whole and partial carcass condemnations and abscesses seem to be the predominant findings. The MI findings of these different age categories seem to reflect what is often seen at the farm level. Respiratory infections are common problems in finishing pigs and these are also evident in MI results reported elsewhere (Merialdi et al., 2012). Our results show that in addition to finishing pig herds some sow herds can also have high pleuritis or pneumonia recordings in MI.

Milk spots in the liver are associated with migrating *Ascaris suum* larvae (Roepstorff et al., 2011). Their lower occurrence in sows than in finishing pigs is understandable, because most of these adult animals were likely to have developed immunity against the parasite. Unfortunately, we did not have information about the age of the slaughtered females and in some herds they may have also included a high percentage of gilts.

Tail-biting is a common behavioral disorder in growing pigs (Valros and Heinonen, 2015), but to our knowledge no papers have been published about its occurrence in sows. One reason for this might be the fact that group housing has not been practiced widely and it has become mandatory for pregnant sows in EU since 2013 (Maes et. al, 2016, Peltoniemi et al., 2016). However, according to the long experience in managing group-housed sows in some countries, we conclude that generally tail-biting damage is not a problem in adult sows. Our results show that some females also have tail biting damage, but its aetiology remains unclear. Tail-biting has been found in gilt rearing (Ursinus et al., 2014) and it is also possible that those few females recorded to have tail damage in our study may have been gilts.

According to our data almost 1/5 of animals had at least one MI finding. Such a high figure has not usually been reported in articles, because only herd level data concerning separate MI findings are available. We also found that heavier carcasses had fewer partial carcass condemnations than lighter carcasses. Heavy carcasses are more likely to be from older sows and it is difficult to speculate, why older sows / heavy carcasses would have fewer condemnations than younger sows / lighter carcasses. Individual carcasses with an abscess were clearly more likely to also have other infections, such as arthritis, shoulder ulcers or pneumonia. It is possible that these individuals had had a systemic infection spreading in the body of the animal. Moreover, carcasses with pneumonia were also likely to have pleuritis, which shows that these conditions occurred simultaneously in the study sows. This kind of individual, detailed information would be very valuable in herd health follow-up not only for sow herds but also for herds growing finishing pigs.

Some of the present sow MI findings can be compared with those reported in the few previous studies including MI findings in sows (Cleveland-Nielsen et al., 2004a, Cleveland-Nielsen et al., 2004b, Flesja and Ulvesaeter, 1979, Knage-Rasmussen et al., 2015). An old study by Flesja et al. (1979) collected the MI results of 10 0541 apparently healthy sows. They reported similar results to ours in the percentage of pyemia together with abscesses (4.7% Flesja et al. 1979 vs. 5.7% in our study), at least one pathological lesion (17.0% vs. 18.5% in our study), milk spots (1.5% vs 0.0% in our study), shoulder ulcer (1.1% vs 3.6% in our study), arthritis (1.9% vs. 2.1% in our study), tail biting (0.4% vs. 1.4% in our study), pleuritis (1.4% vs. 1.7% in our study) and pneumonia (0.6% vs. 1.0% in our study). When comparing the MI findings of sows to those of finishers, Flesja et al. (1979) also concluded that abscesses were more frequent in sows, but that lower frequencies for all the other commonly observed lesions were seen in sows than in finishing pigs. However, the definitions of MI findings are not the same in these two studies and their study is relatively old. Therefore, their comparison only sets an example. MI procedures and criteria are not uniform even in different slaughterhouses within the same country, let alone in slaughterhouses among different countries. For example, in Finland, clear differences were found for how pleuritis was recorded in finishers in different slaughterhouses (Hälli et al., 2012). Similarly, Bonde et al. (2010) reported that sensitivities and specificities to detect pathological lesions in different disease conditions varied between Danish slaughterhouses inducing variations in MI results (Bonde et al., 2010). Cleveland-Nielsen et al. (2004b) found generally lower percentages of MI findings than we obtained in our study except for shoulder ulcers. A study that concentrated only on decubital ulcers (possibly comparable to shoulder ulcers in our study), reported a somewhat higher prevalence to that found in our study (Cleveland-Nielsen et al., 2004a). Knage-Rasmussen et al. (2015) tried to use MI findings in estimating their suitability in replacing an animal welfare index but they did not report mean MI findings in detail. As mentioned earlier, however, the recording systems and the study populations in other studies were different and therefore the results are only roughly comparable. There are also inconsistencies in MI recordings due to variations in the description of similar MI findings, which also makes the comparisons difficult (Harley et al., 2012a).

Cleveland-Nielsen et al. (2004b) divided MI data of sows into infectious or welfare-related causes based on a factor analysis. They found that, generally, the prevalence of different lesions was low, but large herd-to-herd variation existed. They suggested that MI might be used as an inexpensive diagnostic tool in herd welfare classification. Other publications have also shared the same opinion (Harley et al., 2012a, Harley et al., 2014, Sanchez-Vazquez et al., 2011). However, Harley et al. (2012b) stated that MI data cannot be used reliably in large scale welfare surveillance schemes until some standardization and reforms have been made. However, we suggest that MI findings of single herds or different herds within one slaughterhouse could well be used in herd health veterinary work and follow-up. The type of basic MI data of sows used in our study are needed to increase overall knowledge about the subject. Moreover, farmers were shown to have recognized the benefit of the utilization of MI data as a tool in herd health work in one study (Devitt et al., 2016). The same study reported that farmers also thought that private veterinary practitioners are important in helping to interpret the MI findings.

Some studies have attempted to use the MI data in combination with other data to evaluate the welfare of sows. For example, Knage-Rasmussen et al. (2015) tried to develop a cost–effective alternative to those welfare assessment methods that are based on costly on-farm data collection. They aimed to combine several databases into one animal welfare index: mortality data from rendering plants, medicine records from national Danish database Vetstat and MI findings from slaughterhouses. However, they concluded that this kind of an index cannot entirely replace on-farm animal-based measurement data. An animal-based welfare index was developed by the Welfare Quality project (Anonymous 2009). This index also includes some MI findings when finishing pigs are evaluated, but not when the data for the index for sows have been collected. Other animal-based indices include: the Animal Needs Index TGI 35L (Bartussek, 1999) and a modification to it, the A-Index (Munsterhjelm et al., 2006). However, neither of these indices include MI findings.

5. Conclusions

Sow mortality in medium to large size sow herds was found to be associated with some of the meat inspection findings in slaughterhouses, specifically: the percentage of females with at least one meat inspection finding and pleuritis. There was also a tendency for an association between mortality and partial carcass condemnation. In contrast to our hypothesis, high mortality was associated with high percentage of MI findings. This study also provided basic MI data that can be used in sow herd health veterinary and follow-up work. In general, sows seemed to have a high preponderance of MI findings. Heavier sow carcasses were less likely to have at least one MI finding. In individual carcasses, abscesses were associated with arthritis, shoulder ulcers and pneumonia. Similarly, pneumonia was associated with pleuritis.

Conflicts of interest

The authors report that there are no conflicts of interest relevant to this publication.

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Table 1. Meat inspection findings of 7 437 slaughtered gilts and sows in 39 study herds and of all finishing pigs slaughtered in Finland during 2014.

Meat inspection finding	N of gilts and sows	Median % of 39 study herds (range)	*Average % of Finnish finishing pigs (N=1 998 124)*[b]
Whole carcass condemnation	158	1.8 (0.0–7.2)	*0.3*
Partial carcass condemnation	1006	11.8 (0.0–34.6)	*7.7*
≥1 meat inspection finding in the carcass	2175	18.5 (0.0–55.1)	*na*
Abscess	619	5.7 (0.0–16.3)	*3.3*
Arthritis	201	2.1 (0.0–13.3)	*3.2*
Liver condemnation	49	0.0 (0.0–11.3)	*na*
Milk spots	57	0.0 (0.0–5.0)	*6.8*
Organ condemnation	44	0.0 (0.0–13.3)	*na*
Pneumonia	87	1.0 (0.0–3.6)	*2.3*
Pleuritis[a]			
All slaughterhouses	1 034	1.7 (0.0–36.4)	*16.7*
Slaughterhouse A	11	1.3 (0.0–4.7)	*na*
Slaughterhouse B	69	1.5 (0.0–5.1)	*na*
Slaughterhouse C	954	26.3 (0.0–36.4)	*na*
Shoulder ulcer	411	3.6 (0.0–22.9)	*na*
Tail biting	4	0.0 (0.0–1.1)	1.4

[a]Because of clear differences in coding practices regarding pleuritis between different slaughterhouses, pleuritis data are presented separately for each slaughterhouse.

[b]Data received form Eva Kaisti, Finnish Food Safety Authority, personal communication, 2016.

na=not available

Table 2. Percentage of females (gilts and sows) with selected meat inspection findings in slaughterhouses. Data were collected from 7 437 females in 39 herds, which have been classified according to their mean mortality (higher or lower than the mean of the study herds, 9.0%).

Meat inspection finding, 7 437 females from 39 herds	High mortality herds[b] median % (range), N=17	Low mortality herds[c] median % (range) N=22	P-value, crude analysis
Carcass weight kg	192.4	185.9	0.3
Whole carcass condemnation	1.3 (0.0–7.2)	1.1(0.0–5.3)	0.04
Partial carcass condemnation	11.2 (0.0–20.0)	10. (0.0–34.6)	0.2
Lean meat percentage	60.3 (48.9–61.9)	58.5 (53.2–63.4)	0.9
At least one MI finding	20.3 (4.2–49.4)	17.2 (0.0–55.1)	0.04
Abscess	7.3 (0.0–15.2)	5.3 (0.0–16.3)	0.1
Arthritis	3.2 (0.0–13.3)	2.6 (0.0–10.8)	0.4
Liver condemnations	0.0 (0.0–11.3)	0.0 (0.0–7.2)	1.0
Milk spots	0.0 (0.0–2.0)	0.0 (0.0–5.0)	0.3
Organ condemnations	0.0 (0.0–13.3)	0.0 (0.0–6.4)	1.0
Pneumonia	1.3 (0.03.6)	0.5 (0.0–3.6)	0.5
Pleuritis			
All slaughterhouses[a]	3.1 (0.0–36.4)	1.3 (0.0–30.5)	0.05
Slaughterhouse A+B	0.9 (0.0–1.9)	0.4 (0.0–3.6)	0.02
Slaughterhouse C	28.5 (10.1–36.4)	14.0 (0.0–30.5)	0.4
Shoulder ulcer	6.7 (0.0–13.3)	2.6 (0.0–6.4)	0.2

[a]For pleuritis determinations, slaughterhouse specific median value was used because of differences in pleuritis coding practices in these slaughterhouses (Hälli et al., 2012).

[b]Mortality higher than 9.0% (the mean of the study herds)

[c] Mortality lower than 9.0% (the mean of the study herds)

Table 3. Results of random effects (herd as group level variable) multivariable logistic regression model of the risk for an individual sow to have an abscess (outcome) in meat inspection in three Finnish slaughterhouses in 2014.

Variable	Categories	Odds Ratio	95 % Confidence Interval, CI	Wald's P
Arthritis	No	Ref		
	Yes	1.9	1.2–2.8	0.002
Shoulder ulcer	No	Ref		
	Yes	2.3	1.7–3.0	<0.01
Pneumonia	No	Ref		
	Yes	6.8	4.3–10.7	<0.01
Constant		0.06	0.05–0.08	<0.01

Table 4. Results of multivariable logistic regression model between pneumonia (outcome) and pleuritis (explanatory variable) in individual sows slaughtered in three Finnish slaughterhouses in 2014.

Variable	Categories	Odds Ratio	95 % Confidence Interval, CI	Wald's P
Pleuritis	No	Ref		
	Yes	24.6	13.9–43.7	<0.01
Slaughterhouse	A	Ref		
	B	0.6	0.3–1.4	0.25
	C	0.2	0.07–0.4	<0.01
Constant		0.01	0.005–0.2	<0.01